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ELASTIC AND INELASTIC SCATTERING OF 18-MeV PROTONS ON ^{20}Ne

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TECHNICAL PAPER proposed for presentation at
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

E-5387

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Measurements of the asymmetry resulting from the scattering of 18 MeV polarized protons from neon-20 have been available for some time. Those experiments were carried out by Boschitz[1] et al. in a double-scattering arrangement at NASA. The interpretation of the polarization data, however, would be more meaningful if values were available for the differential cross section for proton scattering at the same energy. In addition, neon 20 is one of the more interesting nuclei for the calculation of microscopic form factors[2] to describe elastic and inelastic proton scattering. Finally, based on the coupled-channels calculations which describe the scattering of 24.5 MeV protons, de Swiniarski et al.[3] concluded that the ground state rotational band of Neon 20 contains a large ($\beta 4$ = +0.38) hexadecapole deformation. The present experiment was undertaken primarily in order to supply the cross section data as a companion to the existing polarization data, but also to see whether the large hexadecapole deformation was also necessary to describe the scattering at 18 MeV.

The experiments were carried out using the 18.0 MeV proton beam of the University of Colorado variable energy cyclotron. A diagram of

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TM X-52708

the experimental arrangement is shown in figure 1. The gas target was filled with isotopically enriched Ne^{20} to a pressure of approximately 1/2 atmosphere. Particle detection was by lithium-drifted-silicon detectors. The overall energy resolution of the experiment was approximately 80 keV, which was sufficient to resolve almost all known states of Ne^{20} up to about 8 MeV. For elastic scattering and for inelastic scattering to 10 excited states, angular distributions were measured over the angular range $13^{o} < \theta_{LAB} < 165^{o}$, the full range possible within the geometry of the gas target. In addition, more abbreviated $\theta_{LAB} < 90^{o}$ distributions were measured for the elastic scattering and first 2+ at energies 200 keV below and 500 keV above that at which the bulk of the data was taken. Over that energy range, the fluctuations in cross section were of the order of 10 percent, with no systematic variation with energy detectable.

A typical energy spectrum of scattered protons is shown in figure 2. The only states for which the energy resolution of the present experiment is insufficient are the 7.17 - 7.20 MeV doublet, which was not resolved at all, and the 8.71 - 8.79 MeV doublet which was not well enough resolved to allow good cross section data to be extracted at all angles.

Angular distributions for all the states measured are shown in figures 3, 4, and 5. Figure 3 shows the differential cross sections for the ground state, first 2^{+} (1.632 MeV) and 4^{+} (4.25 MeV) which are the first 3 members of the ground state rotational band. All of the calculations reported here will be concerned with these three states. Figures 4 and 5 show the other measured angular distributions, with their previously known spins and energies.

Fits to the elastic scattering and polarization were carried out using the optical model programs SCAT 4 at NASA and the program MERCY at Berkeley. The two best sets of parameters which could be obtained by minimizing the total χ^2 from both cross section and polarization are listed in figure 6. The fits are shown in figures 7 and 8. Figure 7 is the cross section data only and it may be seen that potential 2 yields a somewhat better fit to these data. On the other hand, figure 8 shows the fits

to the available 18 MeV polarization data, and it is clear that potential 1 yields a somewhat better fit. The total χ^2 however, is almost the same for both potentials.

Potential 1 was used as a starting value for the coupled-channels calculations. These were carried out using the program of A. D. Hill, which permitted the coupling of the 0^+, 2^+, and 4^+ levels, deforming both the real and imaginary, as well as the spin-orbit part of the optical potential. The set of calculations shown in figure 9 and 10 shows that the deformation of the spin-orbit potential has very little effect on either the calculated cross section or polarization. Consequently additional calculations were carried out without a deformed spin-orbit potential. The fits obtained for both the elastic cross section and polarization are comparable to those obtained with the optical model. It was necessary to use a value of $\beta_2 = 0.55$, which is slightly larger than reported in reference 3.

An additional set of calculations is shown in figures 11 and 12. Figure 11 shows the cross sections calculated coupling the first three excited states (0^+ - 2^+ - 4^+), and using potential 1. The solid line uses a value of $\beta_4 = 0.28$ as reported by de Swiniarski et al. The dotted line has $\beta_4 = 0$. It is clear that the large value of β_4 is necessary for an adequate description of the 4^+ cross section. It is also clear that neither the elastic nor the 2^+ cross section is very sensitive to the value of β_4. Neither, as shown in figure 12, is either the ground state or 2^+ asymmetry. Also, comparison of figures 11 and 12 with figures 9 and 10 indicates that no great change is introduced in either the elastic or 2^+ calculations by the coupling of an additional state.

Although the quality of all the coupled-channels fit may be improved slightly by adjustment of optical model parameters, it seems unlikely that any of the conclusions will be changed.

One additional calculation was performed for us by Ford and Braley. The nucleus was represented by an axially symmetric 20-particle Hartree-Fock intrinsic state, from which the 0^+ and 2^+ wave functions were obtained by angular momentum projection. A DWBA calculation was thus performed to obtain the 0^+ - 2^+ cross section. The result is

shown in figure 13, together with the macroscopic coupled-channel result for comparison. Both agree with the data through 60^{o}. For larger angles the macroscopic calculation is neither quantitatively nor qualitatively correct. The microscopic HF calculation is qualitatively correct, but the positions of maxima and minima are pushed much too far forward. The same effect may be seen in the elastic scattering part of the coupled-channel calculation, which suggests that the difficulty may be in the description of the relative motion of target and projectile or the optical potential.

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3. R. de Swiniarski, C. Glasshauser, D. L. Hendrie, J. Sherman, A. D. Bacher, E. A. McClatchie. Phys. Rev. Letters, 23, 317 (1969).

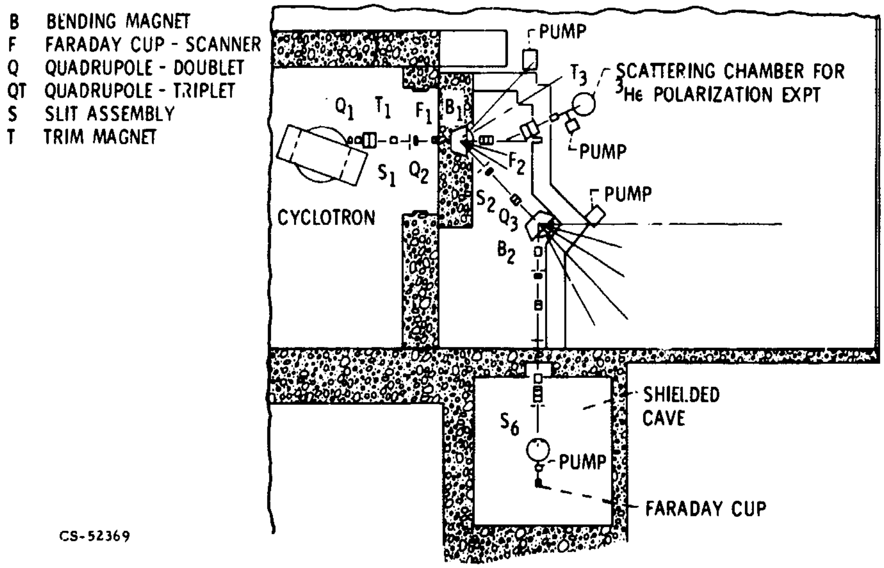

Figure 1. - Beam transport system.

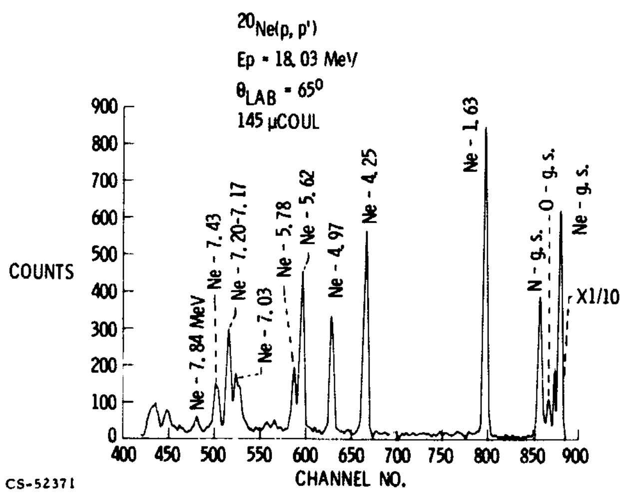

Figure 2. - Typical energy spectrum.

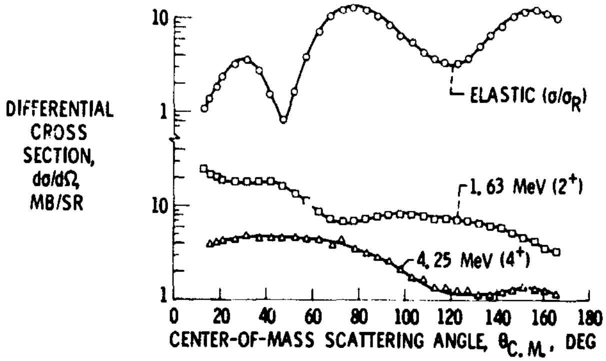

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Figure 3. - Differential cross sections for scattering of 18 MeV protons from Neon-20.

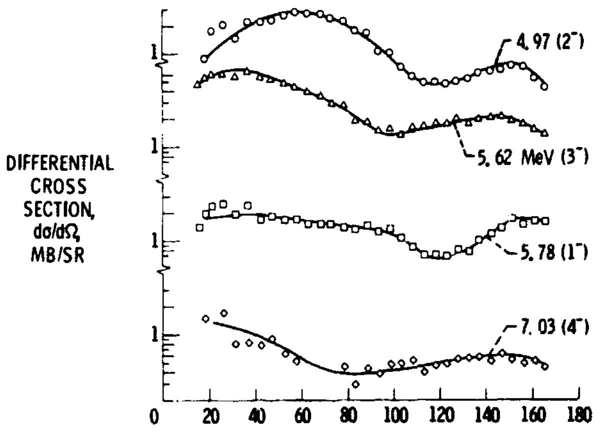

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Figure 4. - Differential cross sections for scattering of 18 MeV protons from Neon 20.

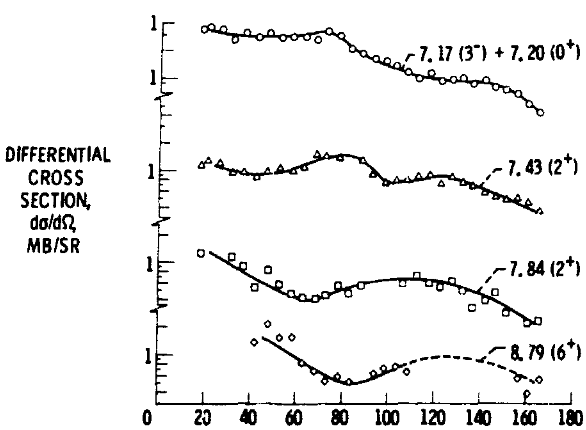

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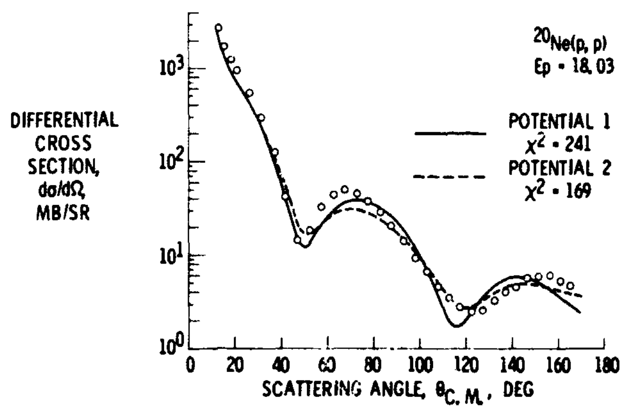
Figure 5. - Differential cross section for scattering of 18 MeV protons from Neon 20.

	REAL		IMAGINARY		SPIN-ORBIT	
	POT 1	POT 2	POT 1	POT 2	POT 1	POT 2
STRENGTH	61.60	48.16	11.42	9.84	3.24	6.49
RADIUS	1.015	1.206	1.293	1.127	1.192	1.197
DIFFUSENESS	0.829	0.694	0.361	0.453	0.344	0.323

CS-52466

Figure 6. - Optical potentials for scattering of 18 MeV protons from Neon 20.



CS-52420 Figure 7. - Optical model fits to elastic scattering.

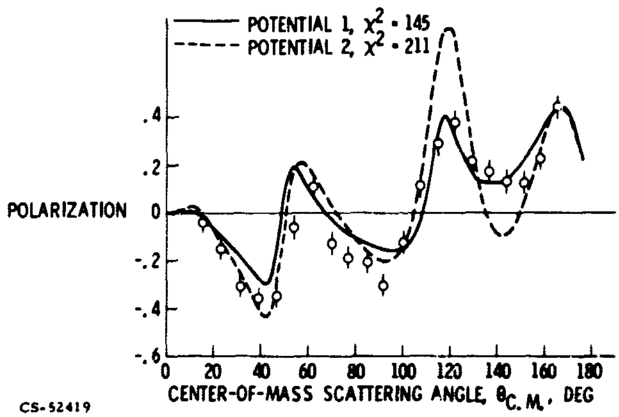


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Figure 8. - Optical model fits to polarization.

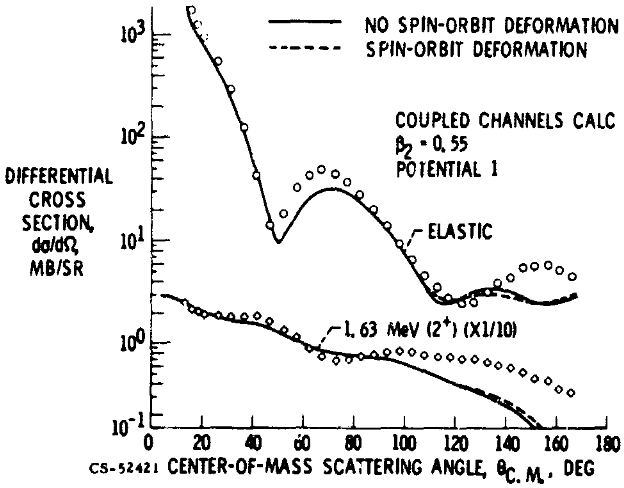

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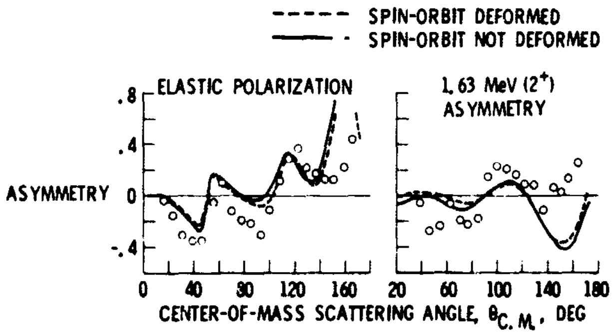
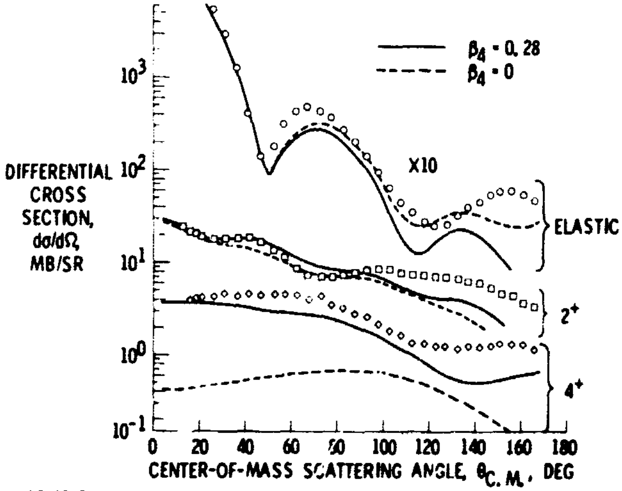
Figure 9. - Effect of spin-orbit deformation on a coupled-channels calculation of cross sections.



CS-52417

Figure 10. - Effect of spin-orbit deformation on a coupled-channels calculation of asymmetry.



CS-52423

Figure 11. - Effect of β_4 on coupled-channels calculation of cross sections.

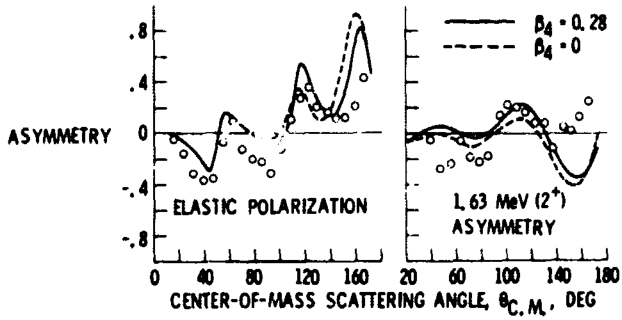


Figure 12. - Effect of β_4 on coupled channels calculation of asymmetry.

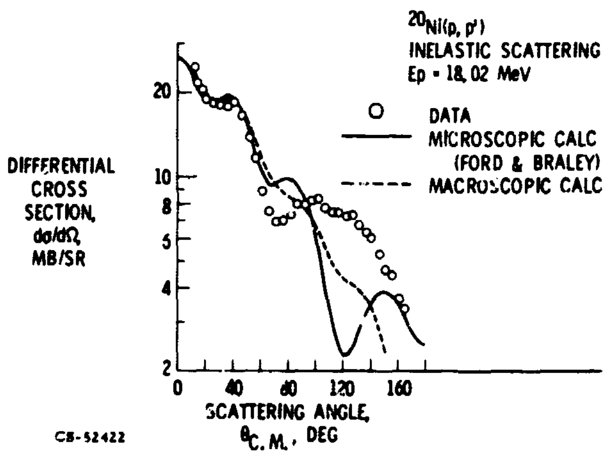


Figure 13